5. MODEL DEMONSTRATION

This chapter demonstrates model capabilities. By applying the model described in Chapter 4 for a study area, an estimation of emissions will be developed. While the conceptual value of the model is revealed through its design parameters, a demonstration provides insight into the model's practical value. The model will predict grams of CO, HC, and NOx, with a spatial resolution determined by the user. In this case, hourly gridded estimates are provided for 100 meter, 250 meter, 500 meter, and 1km grid cells.

The study area is a 100 square kilometer portion of the Atlanta, Georgia metropolitan area and is shown in figure 5.1. The 10 kilometer by 10 kilometer slice of the northeast suburbs was selected as a sample study area because it contains: diverse landuse, variable densities of development, a major interchange, major north-south arterials (leading to the CBD) and an interstate known for congestion (northern portion of I-285).

The following input datasets were used:

- *1995 Georgia Department of Motor Vehicles Registration Dataset*
- *1990 US Census Summary Tape File 3a*
- *1994 US Census TIGER File*
- *1995 Updated TIGER Road Database*
- *1995 Atlanta Regional Commission's (ARC) Traffic Analysis Zones*
- *1995 ARC's Travel Demand Forecasting Network*
- *1995 ARC's Land Use Data*
- *1996 ARC's ARCMAP Road Database*

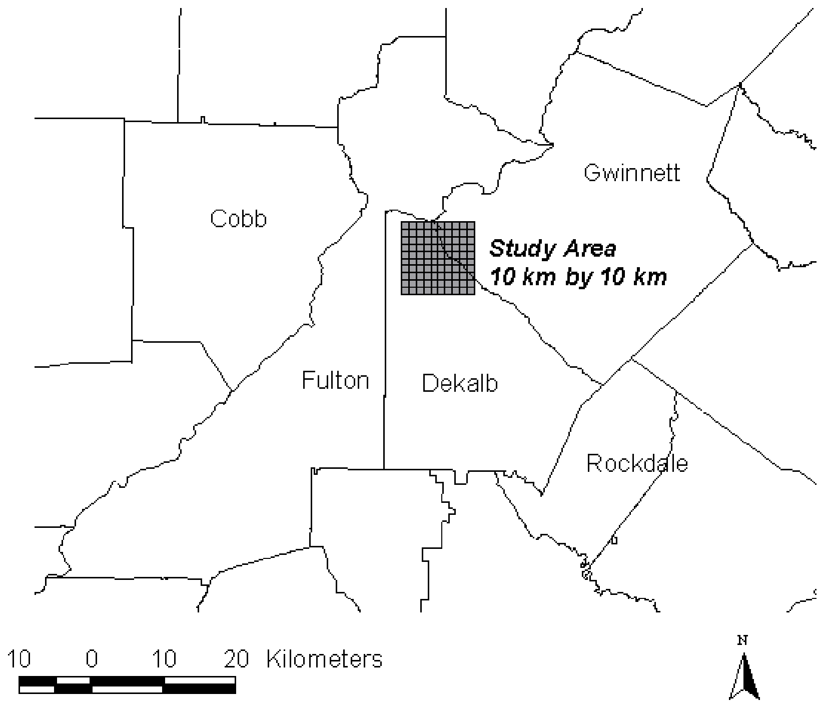

Figure 5.1 - Model Study Area Site Map

5.1. Preprocessing

Several preprocessing steps were completed to prepare model input data. Most model implementation efforts will require substantial preprocessing steps due to the variability of data availability. In this sample case, preprocessing was needed for the road network and vehicle characteristics development. Other data required simple conversion or transformation. Several preprocessing steps were needed.

5.1.1. Vehicle Characteristics

The Georgia DMV Registration Database is protected under privacy regulations. The Georgia Tech Air Quality Laboratory (AQL) has data access permission for research (under contract). To protect the privacy of vehicle owners, a three step 'double-blind' procedure was used to provide vehicle data. First, data consisting of owner address information and a unique identifier were transferred from the AQL. Second, the data were address-matched (in the GIS), and aggregated to Census Block or ZIP code. A file of the unique identifier and the zonal identifier was transferred back to AQL. Third, a file of the zonal identifier and vehicle identification number (VIN) was returned from AQL, thereby providing a spatially-resolved, decodable, file of vehicles.

Address-matching provides the ability to develop vehicle registration information at a better spatial resolution than provided by ZIP codes. The vehicle file was address-matched using two road datafiles, the ARC's ARCMAP Road Database and the road database. The ARCMAP database provided comprehensive coverage for the entire metropolitan Atlanta area. The road database provided higher spatial accuracy, but did not cover the entire area. The road database was used first, to maximize spatial accuracy, and then the ARCMAP was used to maximize comprehensiveness. Actual vehicle locations were offset by 30 meters to ensure that vehicles would not fall on zonal boundaries when aggregated. For a successful match, the ZIP codes must match. Slight errors in spelling were allowed. The road database resulted in a 63% match rate. Another 18% were matched using the ARCMAP road database, for a total of 81%. Therefore, two files were created; one of matched vehicles (81%) and one of unmatched vehicles (19%) (discussed further in chapter 6). The matched vehicles were aggregated to US Census Block (*census)* polygons as described in the previous paragraph.

The two files were sent to the *vehicles.mak* PC process [see figure 4.6]. This process was developed by John Leonard, William Bachman, and Osama Tomeh at

Georgia Tech in 1996 [Tomeh, 1996]. The process reads a file consisting of a record identifier and VIN. During the process, the VIN is decoded using software developed by Radian International Corporation, the vehicles emission test weight was added using a lookup table, vehicles are flagged as being high or normal emitters, and emission-specific characteristics are written to an output file (record identifier, vehicle characteristics, emitter types). Each of the files was sent through this process resulting in the two files required as inputs to the emissions model.

5.1.2. Conflation

Conflation is the process of combining two separate line datasets into a single dataset. In the model, the prognostic data (volumes and speeds) provided by the travel demand forecasting network are transferred to a road network that has better spatial accuracy. There is not a one-to-one correspondence between the two datasets' road segment representation, nor are there attribute fields that can create connectivity. The abstract spatial structure of the travel demand forecasting network prevents a clearly-defined locational connectivity. However, enough spatial definition exists that a manual link-by-link assessment can establish connectivity. The process of conflation is frequently used by transportation agencies to bring various linear datasets together.

The sample area's portion of the travel demand forecasting network consisted of 532 links, and the accurate road database consisted of 3602 road segments. Overlaying the datasets in the GIS (ARC/INFO) identified representational similarities. As individual travel model links were 'selected', corresponding accurate road segments were also selected. The NAVTECH roads were assigned an identifier field that could be used to transfer attributes (predicted volume, speed, etc.). Each of the 532 was processed in this manner. The resulting database is one of the required inputs into the model.

5.1.3. Other Steps

Numerous other steps were needed to fully prepare data for model running. The databases are all distributed in different formats, requiring conversion, transformation, and renaming. Atlanta area Census data (STF3A and TIGER) had to be selected, joined, and transformed to develop the zonal database containing detailed household information. The ARC's travel demand forecasting network had to be converted from an ASCII file to an ARC/INFO coverage using programs written by Wayne Sarasua, Xudong Jia, and William Bachman at Georgia Tech. The ARC's TAZs and land use were delivered in an ARC/INFO coverage. Other urban areas may have to develop customized strategies to get the input information in the format described in the previous chapter, and in the data dictionary found in the appendix.

5.2. Spatial Environment

The spatial environment consists of the ARC/INFO input coverages: *taz* (Atlanta Regional Commission's (ARC) traffic analysis zones), *census* (US Census blocks), *landuse* (ARC's landuse), ZIP*code*, and *allroads* (conflated road database). The spatial environment output coverages were: *sz* (engine start polygons), *mr* (major road running exhaust lines), and *mz* (minor road running exhaust polygons). Figures 5.2 and 5.3 demonstrate the connectivity.

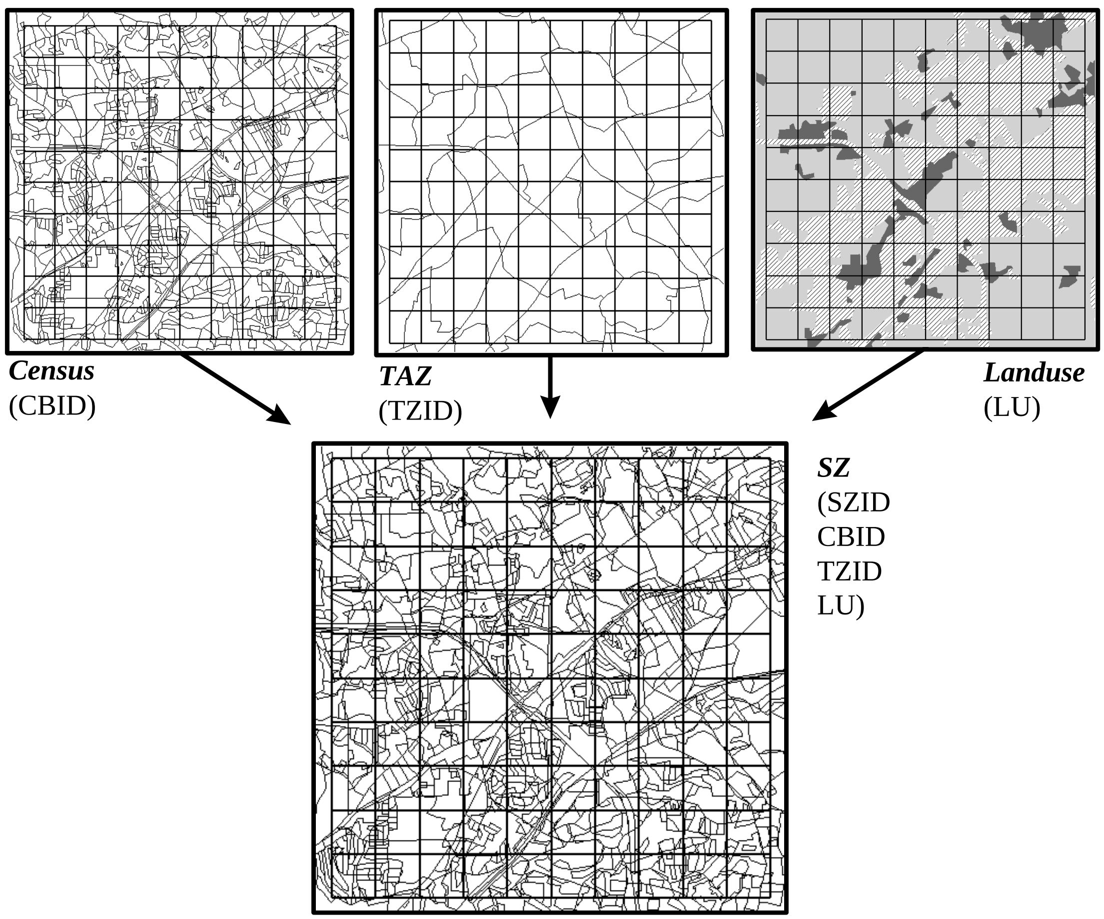

Figure 5.2 - Engine Start Zone Creation

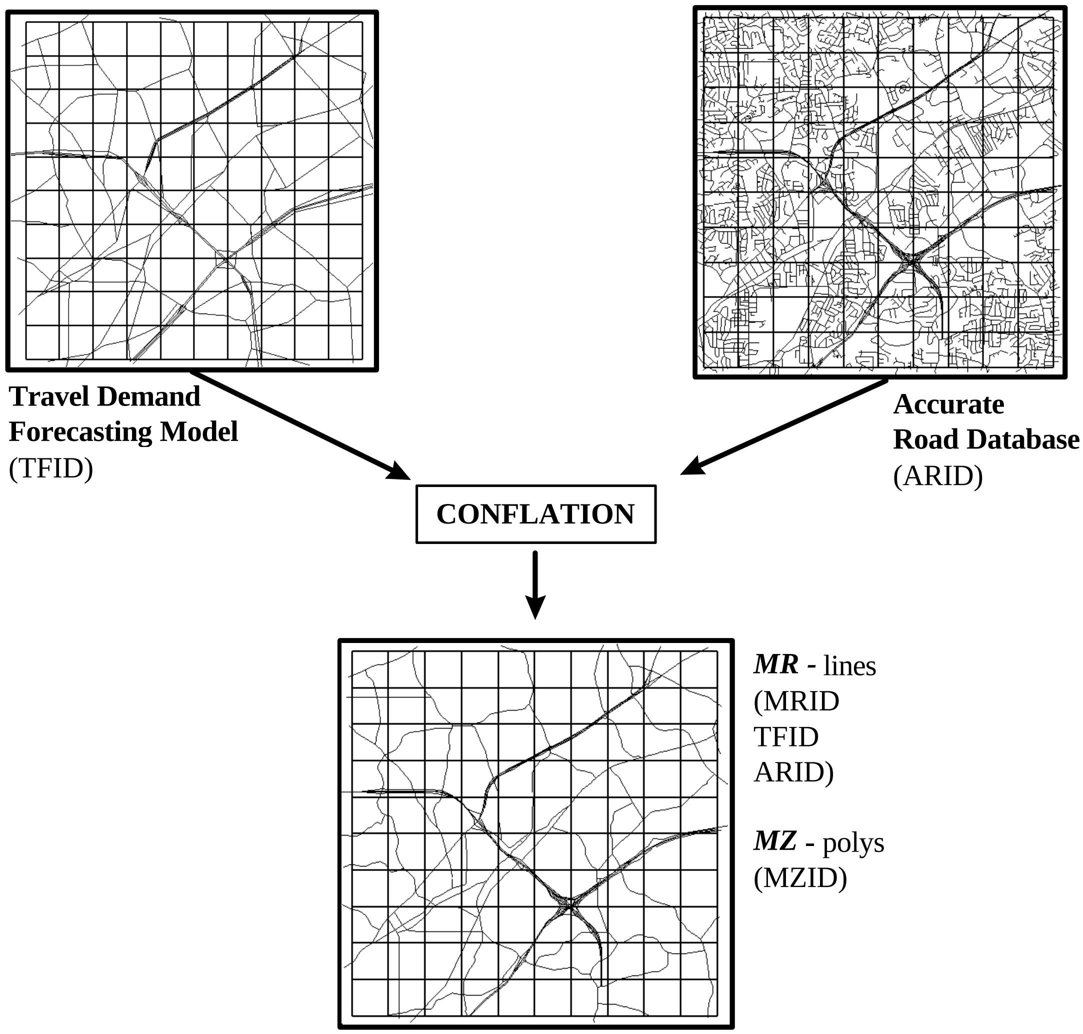

Figure 5.3- Running Exhaust Entity Creation

5.2.1. Engine Start Polygons

Engine start polygons (*SZ*) consist of spatially joined features from *taz, census, landuse,* and z*ipcode.* The 1624 SZ polygons had a mean area of 72,746 square meters. Most of the polygons are identical to smallest input polygons, generally, the US Census blocks. Each SZ polygon maintains identifiers to the original databases in a one-to-one or many-to-one relationship.

5.2.2. Running Exhaust Lines and Polygons

Running exhaust lines and polygons (*MR* and *MZ*) consist of conflated travel demand model network segments and areas bounded by those segments. The segments represent roads that have prognostic estimates of travel behavior from the ARC. The polygons represent the roads that have road-specific estimates of travel activity. The road segments had a median length of 202 meters. The median of the 205 minor zones is 487,815 square meters.

5.3. Fleet Characteristics

The fleet characteristics were developed from the two files described in section 5.1.1. Five fleet distribution databases were created by the model from the two files; *es.tg* (zone-based engine start technology groups), *re.tg* (zone-based running exhaust technology groups), *scf.tg* (zone-based SCF technology groups), *rereg.tg* (regional running exhaust technology groups) and *mr.tg* (major road running exhaust technology groups). The files contain identifiers that connect records to spatial entities (*sz* or *mr*).

5.3.1. Model Year Distributions

The distributions of vehicle model years predicted by the model for the sample area are shown in Figure 5.4. The figure shows the entire sample area's mean distribution and two sample *sz* polygon distributions. The sample size for the zone with SZID of 2176 was 109 vehicles and SZID 209 was 126 (zonal frequencies varied from zero to several hundred). The entire area's mean frequency was 49. In Chapter 6, a comparison between observed and estimated model year distributions is presented.

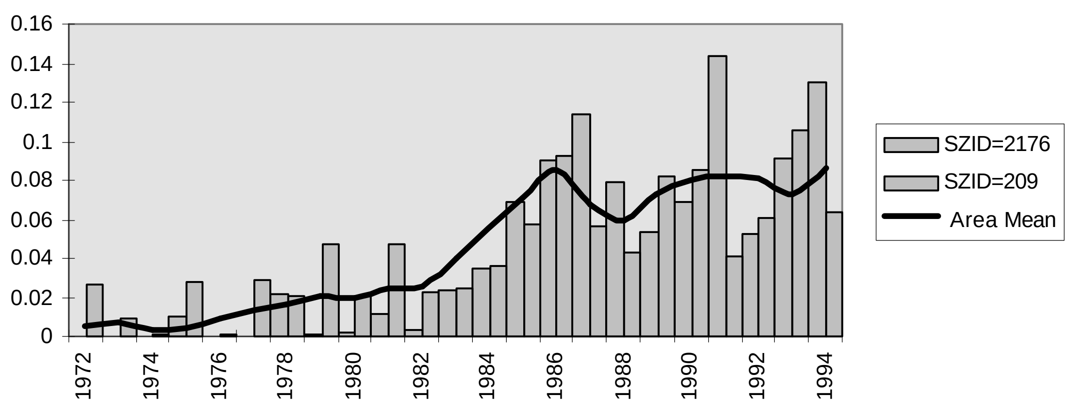

Figure 5.4 - Model Year Distribution

5.3.2. High Emitters

High emitting vehicles were defined in one of the preprocesses [see section 3.4.2.3]. In the process, vehicles are randomly selected from four groups of vehicles, each having different likelihoods of being high emitters. The ‘flagged’ vehicles are then characterized as high emitters. The resulting sample area high emitting vehicle distributions are shown in figure 5.5. The figure shows a dot density map of all engine starts, CO high emitters, HC high emitters, and NOx high emitters. The two circles identify locations with high numbers of engine starts, but low numbers of high emitter starts, suggesting that the likelihood that a vehicle is a high emitter, varies spatially. Although this can’t be validated until other model components are validated, it does suggest a possible value of the model.

5.4. Vehicle Activity

The sample area vehicle activity was developed from the Atlanta Regional Commission’s (ARC) Travel Demand Forecasting Model dataset. Supplemental information came from 11 speed and acceleration profiles and temporal factors from Parsons Brinkeroff Inc.

5.4.1. Engine Start Activity

Engine starts were developed from trip generation data at the ARC’s traffic analysis zone level. Trips were disaggregated to *SZ* coverage polygons based on the ARC’s 1995 land use data, 1990 US Census STF3A data housing unit densities, 1994 US Census TIGER data, and school and university landmarks developed by Georgia Tech. The AM peak hour engine starts spatial distributions is shown in figure 5.5.

The engine start temporal distributions were developed using half hourly distributions by trip type (home-based-work, home-based-shopping, home-based-other, home-based grade school, home-based-university, and non-home-based). Figures 5.6 through 5.10 show the hourly distributions of the trip origins, directly translated to engine starts. The non-home-based are not disaggregated by origin and destination because there is no information regarding the origins or destinations.

5.4.2. Running Exhaust Activity

Running exhaust activity was estimated for major roads and minor roads. Minor roads consisted of all roads not explicitly modeled in the ARC's travel demand forecasting model. Major road were explicitly modeled by ARC for daily activity using

The Urban Analysis Group's TRANPLAN product. The network used in the TRANPLAN model was conflated to accurate roads.

Minor road running exhaust activity was predicted using the engine start activity estimates for each *SZ* zone, and the shortest network path from the centroid of that zone to the closest *MR* line. An average travel time for each path was determined using an average travel speed of 30 MPH. The aggregate travel time for activity in each *MZ* became the estimate of minor road vehicle activity.

Major road running exhaust activity was developed directly from the TRANPLAN output, and associated speed and acceleration profiles. Figure 5.11 represents the spatial distribution of peak hour volume density. Figure 5.12 shows the temporal distribution used to divide daily activity into hourly segments. Eleven speed and acceleration profiles were used to predict modal activity; five for each LOS on interstates, five for each LOS on interstate ramps, and one for all other roads. The data for one speed and acceleration profile used for the non-interstate, non-ramp, roads were collected on a major arterial between signalized intersections.

Road grade data were available for approximately 25% of the interstates running through the sample area. All roads without grade information were assumed to have a zero grade. Roads with grade information had the grade distribution segmented into five intervals.

5.5. Facility and Gridded Emissions

The emissions estimates for the sample area were developed for engine starts and running exhaust activity. Engine start emissions were developed for each *sz* polygon. Running exhaust emissions were developed for *mz* polygons and *mr* lines. All estimates are in grams. The gridded estimates were aggregated from the facility entities at 100, 250, 500, 1000 and 2000 meter grid cell sizes (the value refers to the length of one cell side, not the cell's area). The various sizes were developed to explore and demonstrate the impact of grid cell size on the emissions estimate. Figures 5.13 through 5.19 represent the 100 meter grid cell aggregation in a surface (with an overlay of 500 meter grid lines). Figures 5.20 - 5.22 show temporal distributions of emissions.

5.5.1. Engine Start Emissions

Engine start emissions are shown in figure 5.13. The figure shows a three-dimensional surface where *x* and *y* are geographic coordinates and *z* is adjusted value for engine start emission estimate. The value is adjusted to spatially identify relative emission estimates. The individual ‘spikes’ show estimated high concentrations of engine start emissions. Given the hour of the day (7-8 AM) the majority of the emissions from engine starts occur in residential areas. Thus, areas with large populations (resulting in large numbers of engine starts) combined with higher emitting vehicles spatial distributions will have high emissions. In the figure, the highest spikes in the north east corner of the map are locations of dense multi-family development.

The total 24-hour engine start CO estimated for the area is 15,768,000 grams, the total estimated HC is 347,000 grams, and the total estimated NOx is 571,000 grams.

5.5.2. Minor Road Running Exhaust Emissions

Minor road running exhaust emissions are shown in figure 5.14. The same format as described in section 5.5.1 is used for the figure. As seen from this figure, spikes of intense emissions are not prevalent. This is due to the highly aggregate nature of estimating local road activity to large polygons. However, variability is evident among zones, indicating the impact of the road network configuration on travel time.

The total 24-hour minor road running exhaust CO estimated for the area is 1,195,000 grams , the total estimated HC is 50,000 grams, and the total estimated NOx is 60,000 grams.

5.5.3. Major Road Running Exhaust Emissions

Major road running exhaust emissions are shown in figure 5.15. As expected emission ‘spikes’ fall along the major road (shown as white lines). The highest spikes fall along the interstates. Arterials, especially the Peachtree Industrial Blvd - Peachtree Road arterials, show significant emissions as well. The emissions estimates are not linear with volume, as appears, but are affected by the predicted modal behavior. When speed and acceleration profiles are used that have high variability (arterials, or low LOSs), there are higher emissions.

The 24-hour major road total running exhaust CO estimated for the area is 18,375,000 grams, the total estimated HC is 734,000 grams, and the total estimated NOx is 811,000 grams.

5.5.4. SCF Running Exhaust Emissions

Figure 5.16 represents speed correction factor (SCF) running exhaust emissions. Again, the emission spikes fall along the major roads. However, the emissions along arterials do not appear as significant as the previous figure. Mostly, this is due to the use of average speed as the measure of vehicle activity, excluding the effects of variable acceleration and deceleration. Thus, arterials and poor LOS road segments may have poorly represented emission estimates. While the level of spatial aggregation used for reporting (4-5 km grid cells) may negate this impact, it is clear that facility-level and smaller grid cell aggregations of emission estimates will be affected.

The total 24-hour SCF running exhaust CO estimated for the area is 17,045,000 grams, the total estimated HC is 1,236,000 grams, and the total estimated NOx is 4,432,000 grams.

5.5.5. Total Emissions

The total emissions estimates were developed by adding the 100 meter aggregations of engine starts, minor road running exhaust, and major road running exhaust (aggregate modal). Total emissions for the study area are represented in figures 5.17 to 5.22. Figures 5.17 to 5.19 show emissions estimates for CO, HC, and NOx, between 7 and 8 AM. Figures 5.20 to 5.22 show the temporal variability found in the estimates occurring between 6 AM and 9 PM. The CO and HC estimates are characterized by the major road emissions and the spikes of engine start emissions. The NOx estimates are characterized by emissions on the major roads.

The figures showing temporal variability identify the impacts of the distributions seen in figures 5.6 through 5.12. It appears from the figures, that engine start emissions dominate the off-peak emissions, while running exhaust emissions dominate the peak hour emissions. This may be a function of the impact of congestion on the roads (higher variability in modal activity) during high traffic times. There also appears to be an unusual amount of engine start activity between 3 and 4 PM. Reviewing the temporal curves, all trip types except home-based-work are high between 3 and 4 PM.

5.6. Conclusion

Chapter 5 presented the results of model runs on a 100 sq. km area in northeast Atlanta, GA. The results of each module are presented along with detailed descriptions of the input data. Outputs are described in detailed as well.

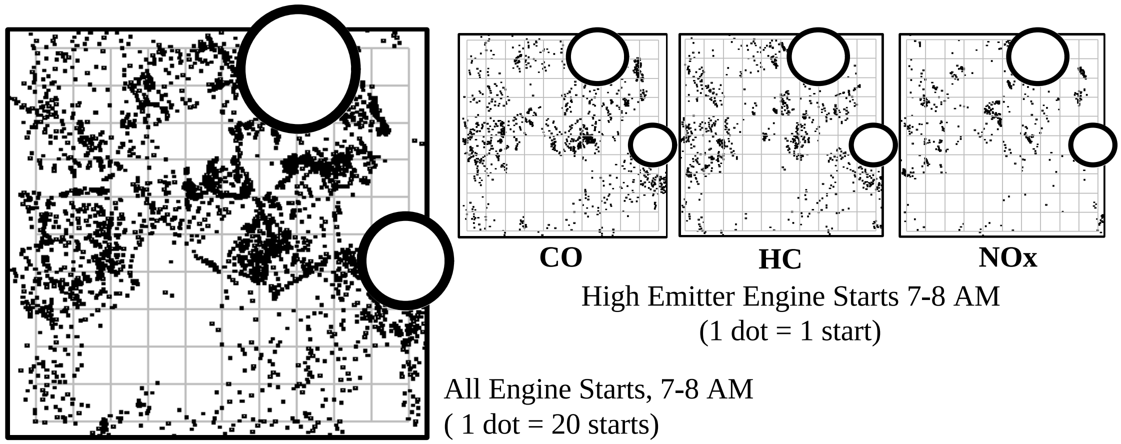

Figure 5.5 - High Emitter Engine Starts, 7-8 AM

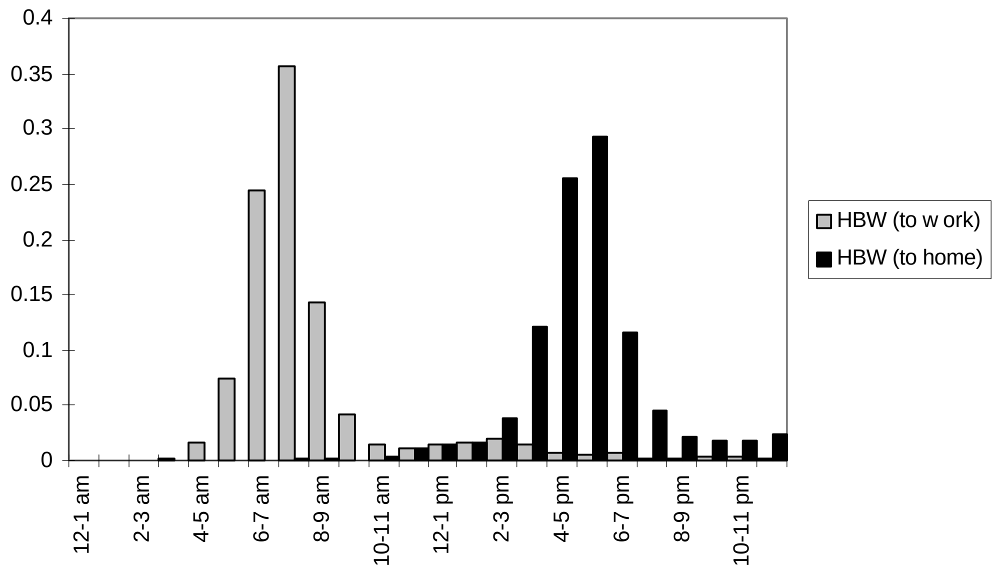

Figure 5.6 - Home-Based Work Trip Temporal Distribution

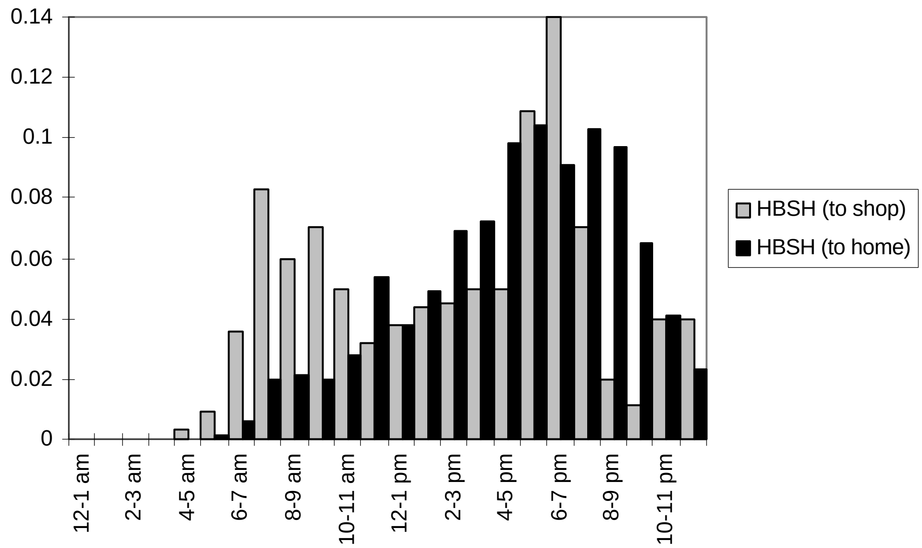

Figure 5.7- Home-Based Shopping Trip Temporal Distribution

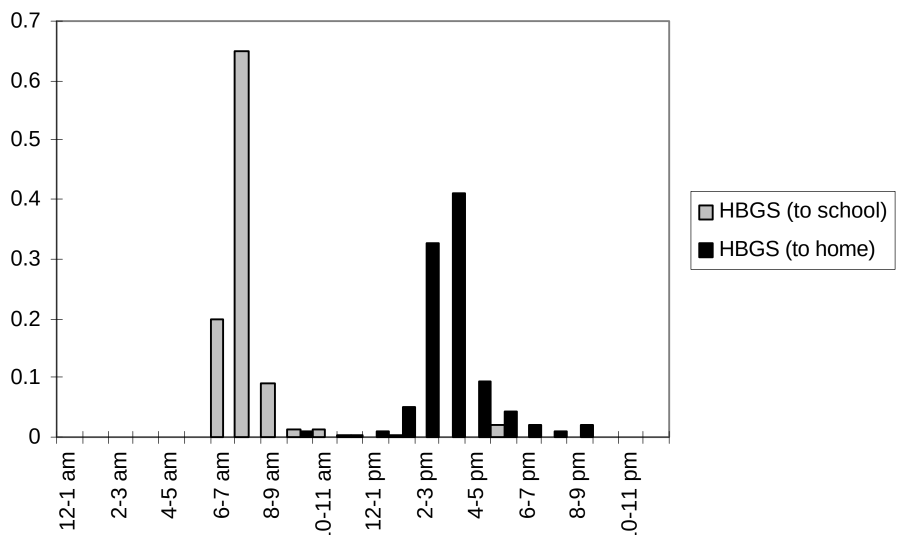

Figure 5.8 - Home-Based Grade School Trip Temporal Distribution

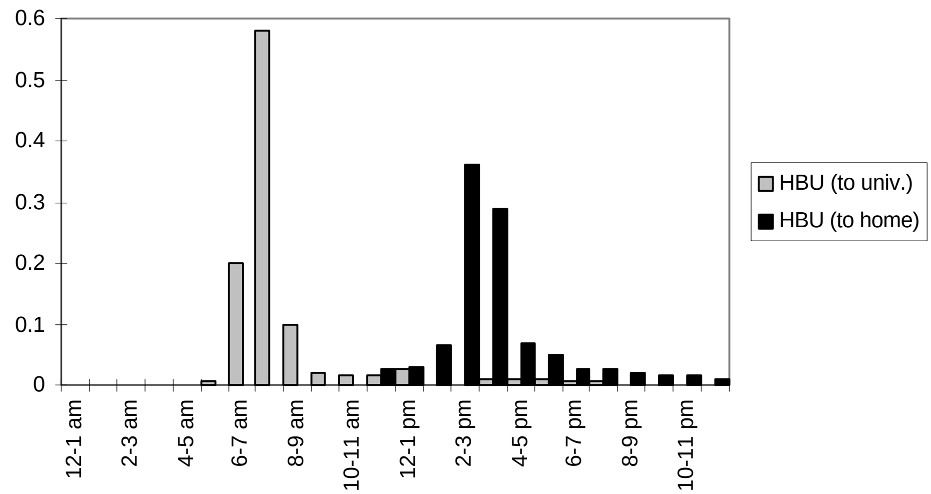

Figure 5.9 - Home-Based University Trip Temporal Distribution

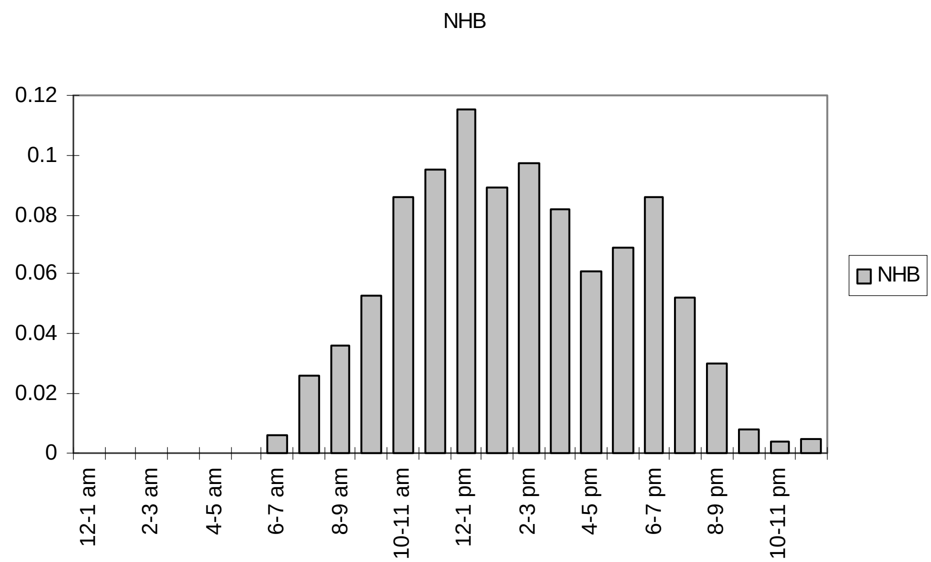

Figure 5.10 - Non-Home-Based Trip Temporal Distribution

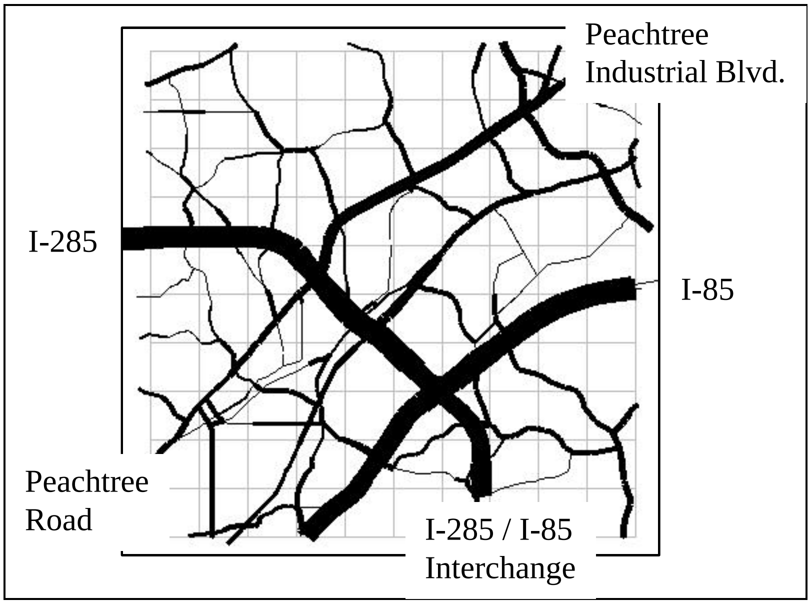

Figure 5.11 - Road Volume Density

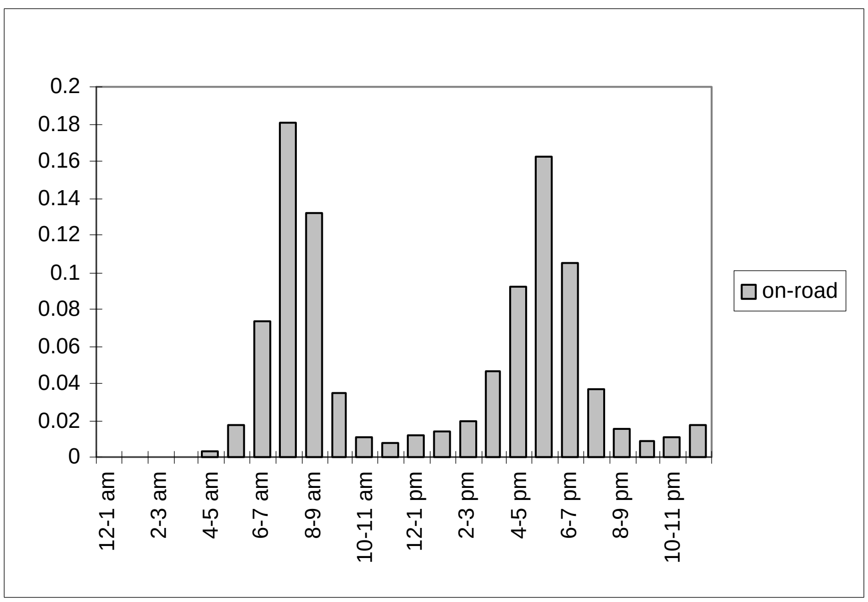

Figure 5.12 - On-Road Activity Temporal Distribution

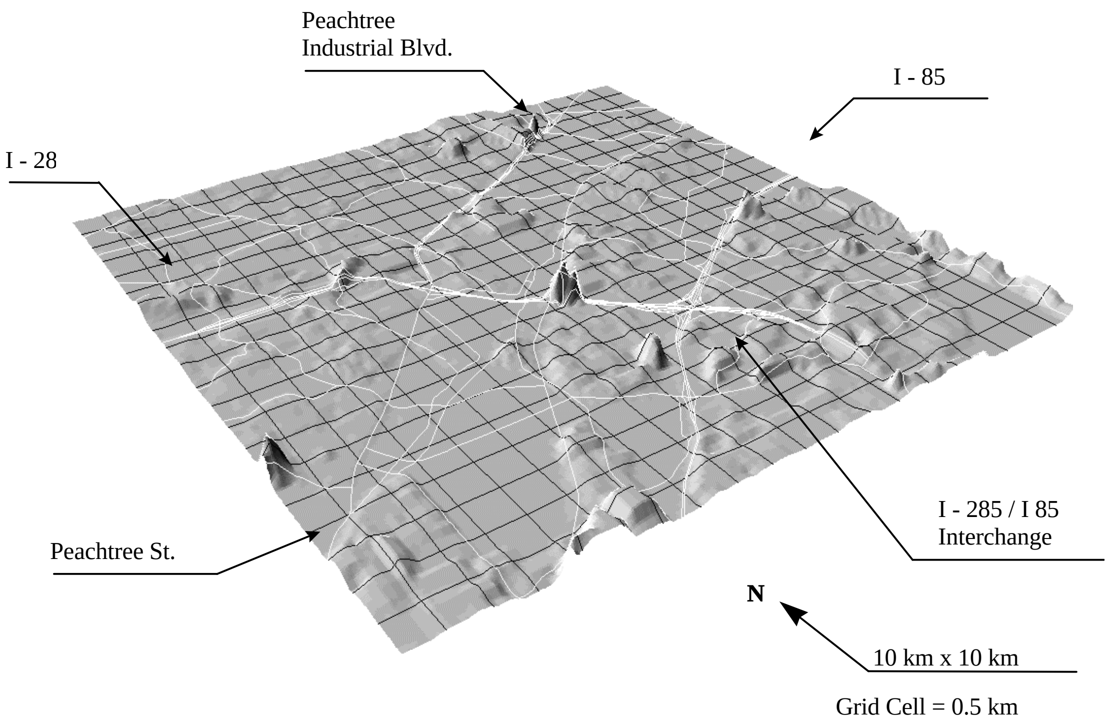

Figure 5.13 - Engine Start CO, 7-8 AM

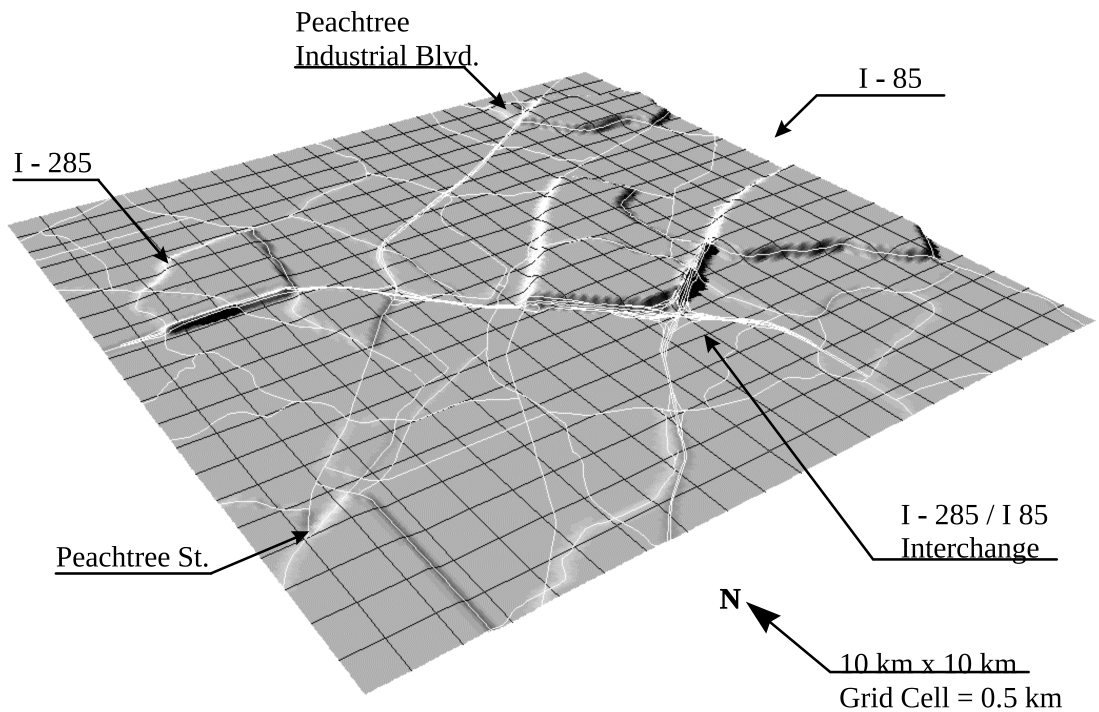

Figure 5.14 - Minor Road Running Exhaust CO, 7-8 AM

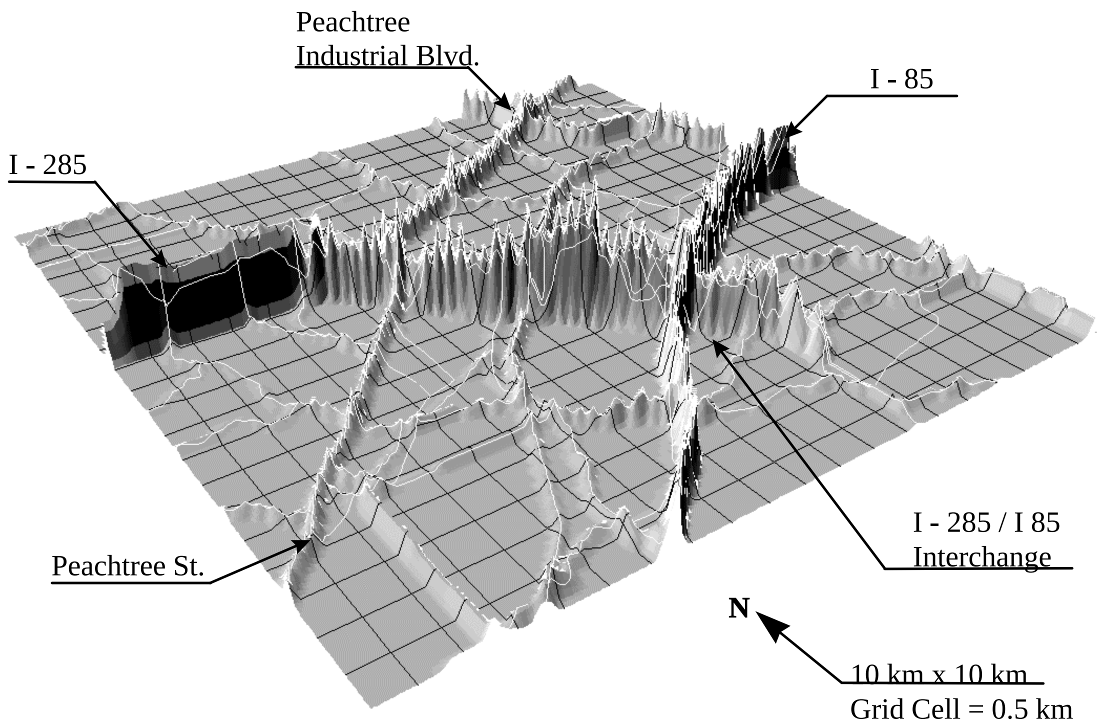

Figure 5.15 - Major Road Running Exhaust CO, 7-8 AM

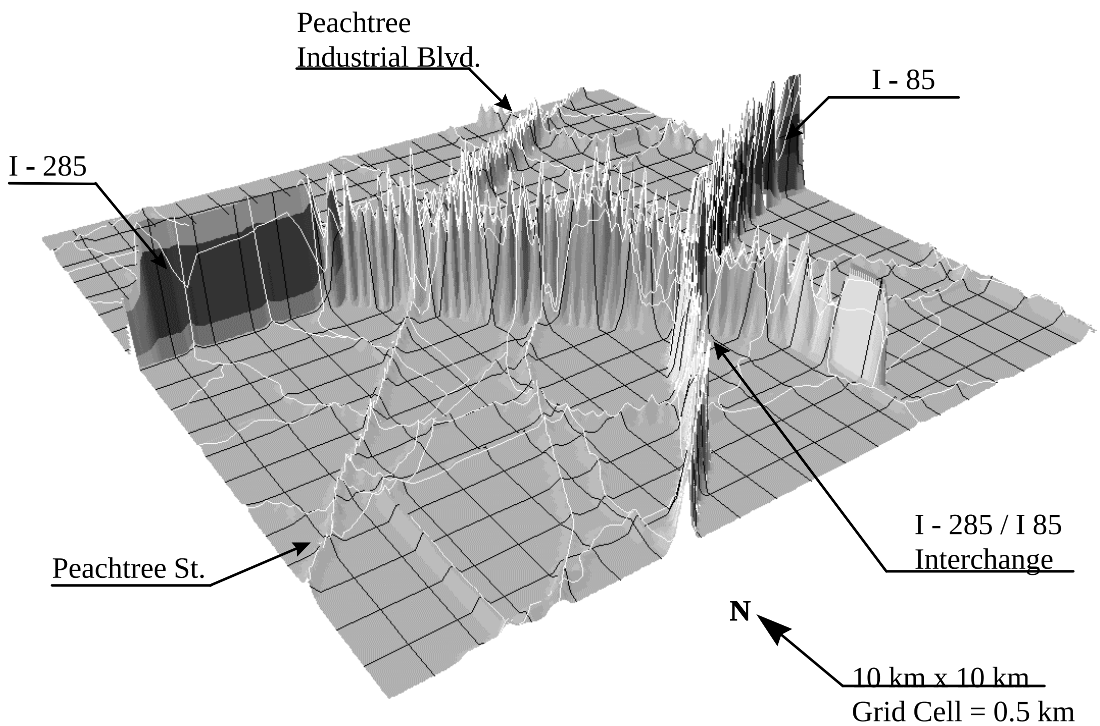

Figure 5.16 - SCF Running Exhaust CO, 7-8 AM

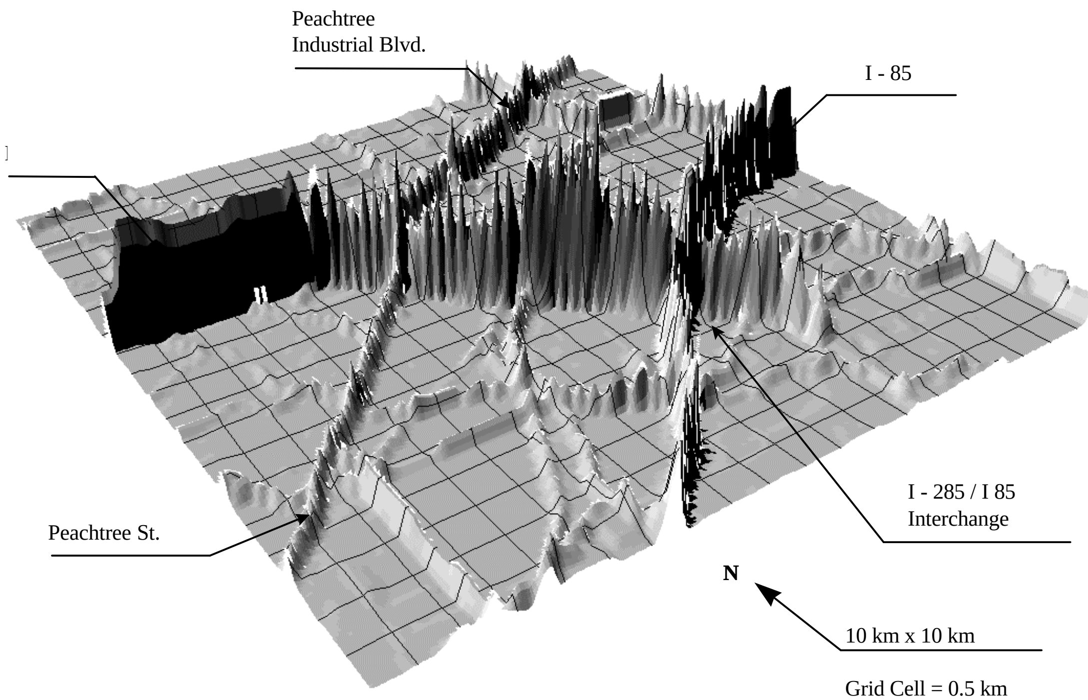

Figure 5.17 - Total CO, 7-8 AM

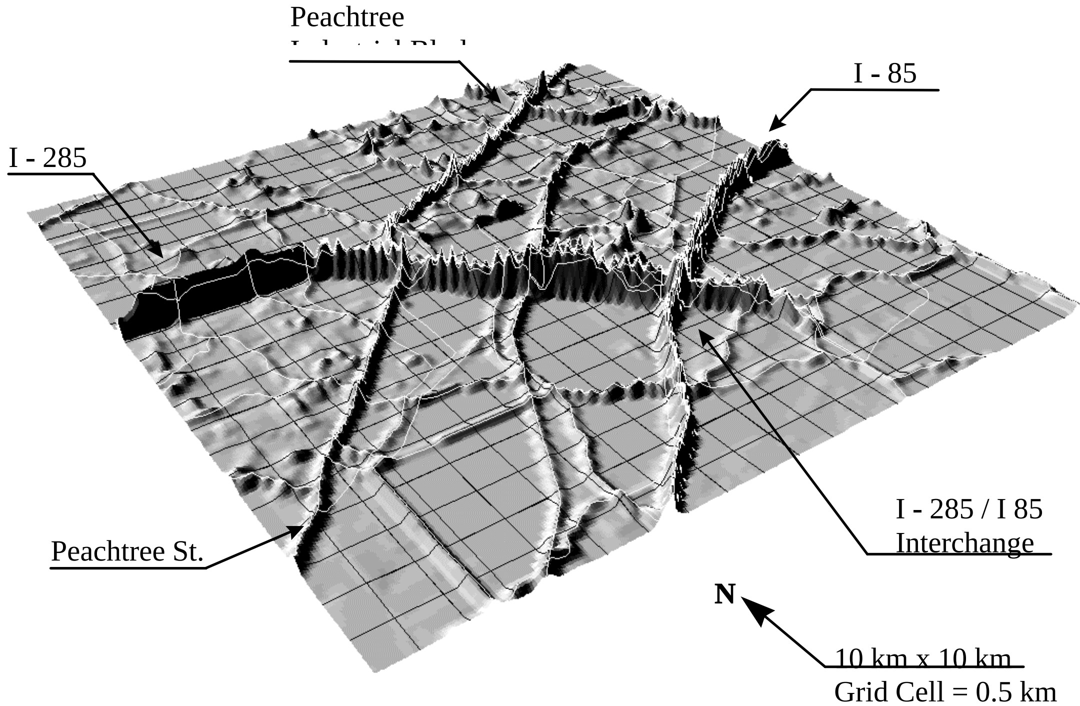

Figure 5.18 - Total HC, 7-8 AM

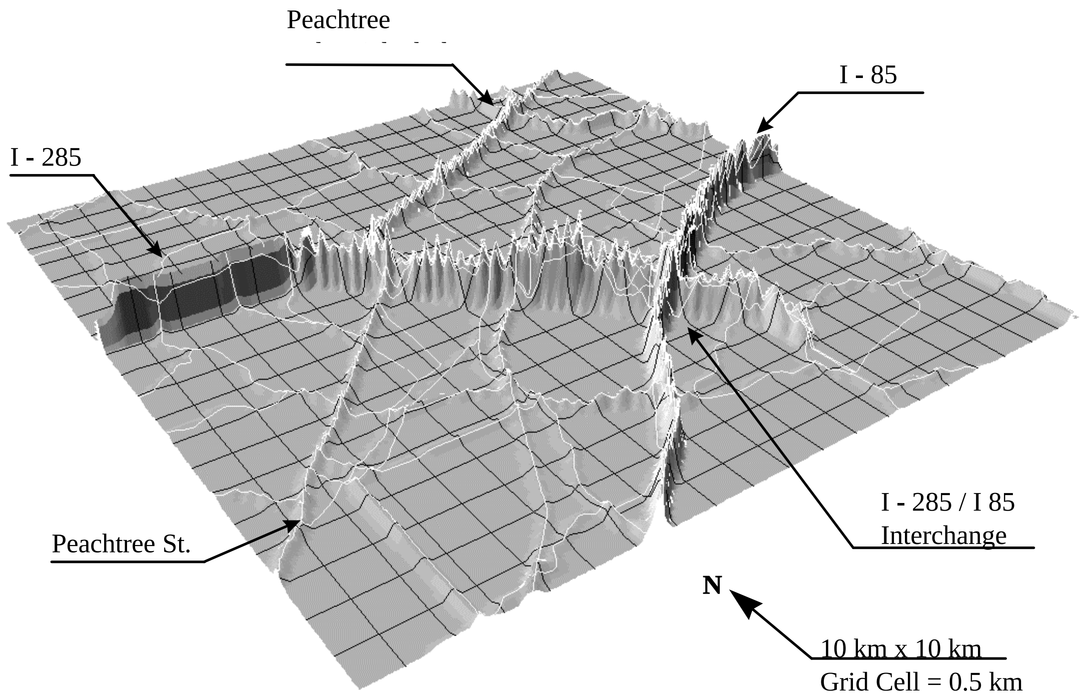

Figure 5.19 - Total NO_x, 7-8 AM

6-9 AM

10 AM - 1 PM

2 - 5 PM

6 - 9 PM

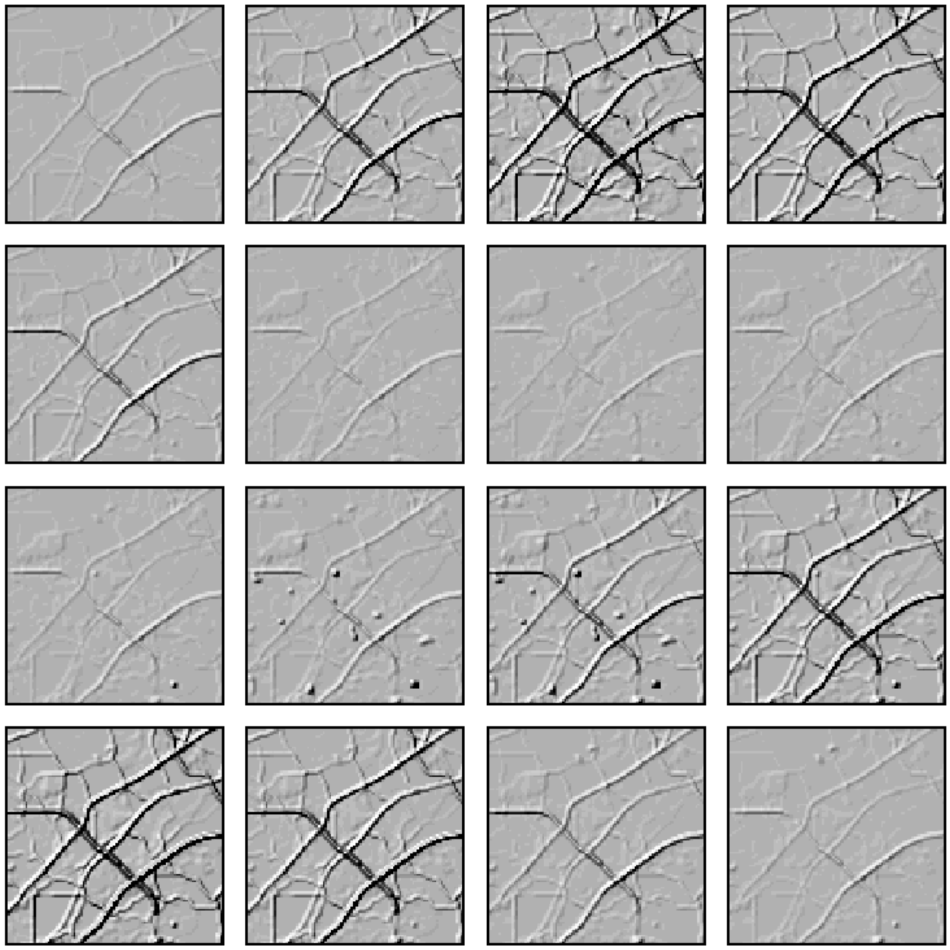

Figure 5.20 - Total CO, 6 AM - 9 PM

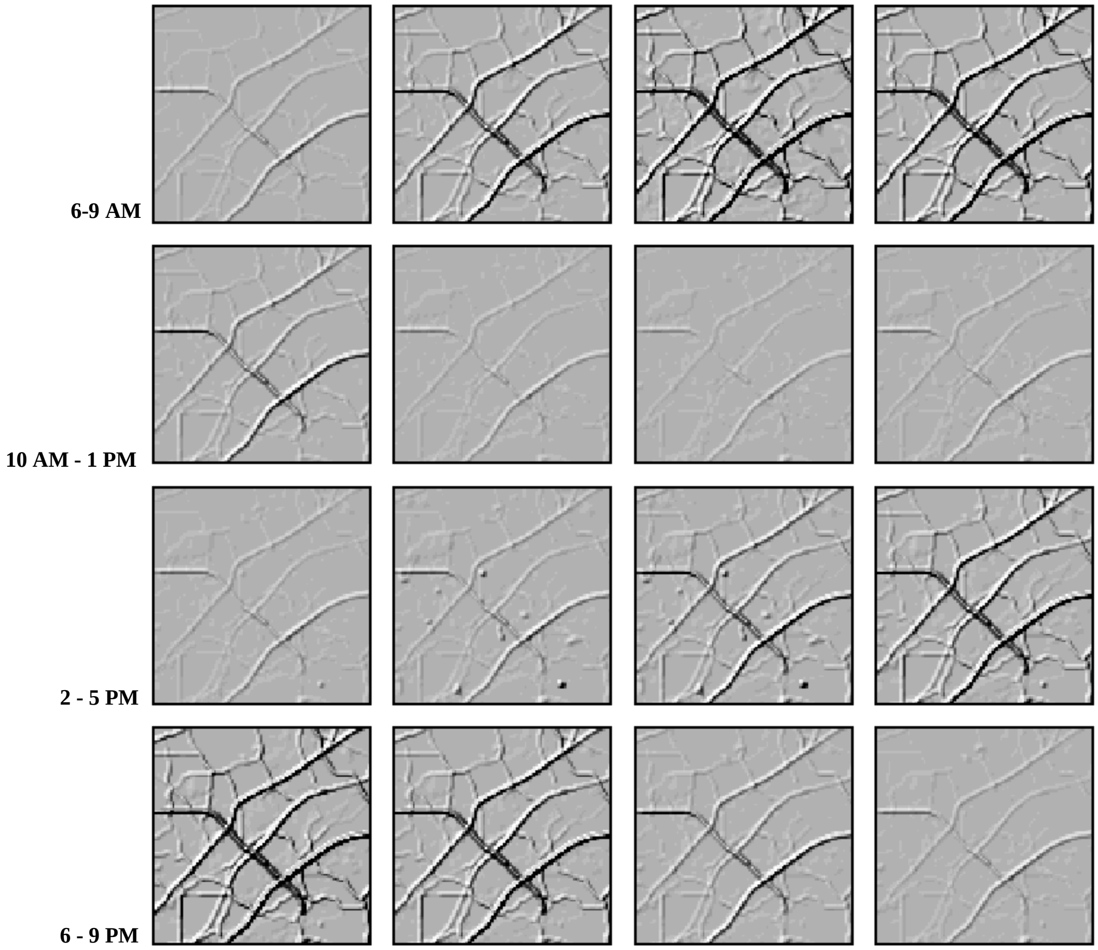

Figure 5.21 - Total HC, 6 AM to 9 PM

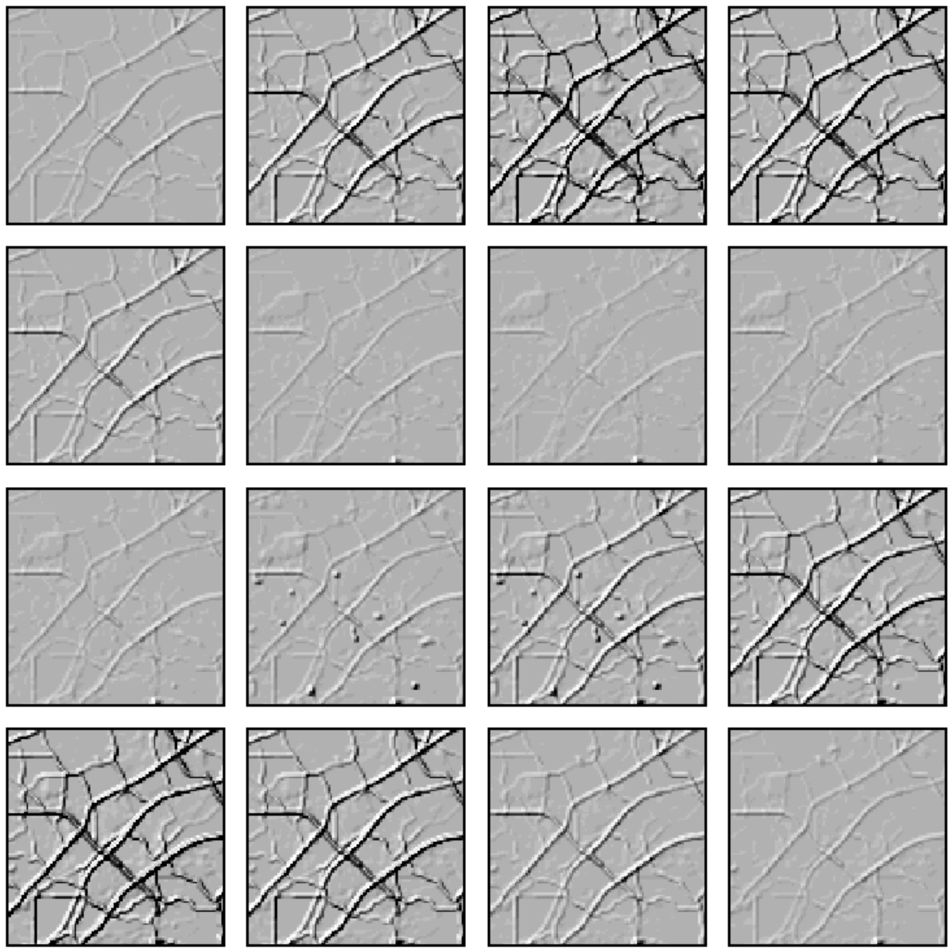

Figure 5.22 - Total NO_x, 6 AM to 9 PM